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A Semiautomated Method for Measuring the 3-Dimensional Fabric to Renal Artery Distances to Determine Endograft Position After Endovascular Aneurysm Repair

Richte C. L. Schuurmann, MSc[1,2], Simon P. Overeem, MSc[1,2], Kenneth Ouriel, MD[3], Cornelis H. Slump, PhD[4], William D. Jordan Jr, MD[5], Bart E. Muhs, MD, PhD[6], and Jean-Paul P. M. de Vries, MD, PhD[1]

Abstract

Purpose: To report a methodology for 3-dimensional (3D) assessment of the stent-graft deployment accuracy after endovascular aneurysm repair (EVAR). **Methods:** A methodology was developed and validated to calculate the 3D distances between the endograft fabric and the renal arteries over the curve of the aorta. The shortest distance between one of the renal arteries and the fabric (SFD) and the distance from the contralateral renal artery to the fabric (CFD) were determined on the first postoperative computed tomography (CT) scan of 81 elective EVAR patients. The SFDs were subdivided into a target position (0–3 mm distal to the renal artery), high position (partially covering the renal artery), and low position (>3 mm distal to the renal artery). Data are reported as the median (interquartile range, IQR). **Results:** Intra- and interobserver agreements for automatic and manual calculation of the SFD and CFD were excellent (ICC >0.892, p<0.001). The median SFD was 1.4 mm (IQR −0.9, 3.0) and the median CFD was 8.0 mm (IQR 3.9, 14.2). The target position was achieved in 44%, high position in 30%, and low position in 26% of the patients. The median slope of the endograft toward the higher renal artery was 2.5° (IQR −5.5°, 13.9°). **Conclusion:** The novel methodology using 3D CT reconstructions enables accurate evaluation of endograft position and slope within the proximal aortic neck. In this series, only 44% of endografts were placed within the target position with regard to the lowermost renal artery.

Keywords

3D reconstructions, abdominal aortic aneurysm, aneurysm neck, computed tomography, deployment technique, endograft, endovascular aneurysm repair, geometry, imaging, renal artery, stent-graft

Introduction

Endovascular aneurysm repair (EVAR) is being used more frequently to treat patients with challenging aortic neck morphology, such as short or significantly angulated necks.[1–3] Debates on this subject assume full coverage of the available neck, but accuracy of endograft deployment in a regular EVAR case is largely unknown because sophisticated post-EVAR computed tomography (CT) analysis is not performed on a regular basis. Many studies have associated pre-EVAR challenging neck morphology with complications, such as type Ia endoleak and migration,[4–9] but accuracy of the post-EVAR endograft position is not included in these studies. Initial suboptimal deployment of the endograft will reduce the apposition surface in the neck, leading to an increased risk for proximal neck complications.

A methodology for accurate determination of the 3-dimensional (3D) endograft position in the aortic neck with regard to the renal arteries is lacking. The objective of this study was

[1]Department of Vascular Surgery, St Antonius Hospital, Nieuwegein, the Netherlands
[2]Technical Medicine, Faculty of Science and Technology, University of Twente, Enschede, the Netherlands
[3]Syntactx, New York, NY, USA
[4]MIRA Institute for Biomedical Technology and Technical Medicine, University of Twente, Enschede, the Netherlands
[5]Department of Vascular Surgery, Emory University School of Medicine, Atlanta, GA, USA
[6]The Vascular Experts, Middletown, CT, USA

Corresponding Author:
Richte C. L. Schuurmann, Department of Vascular Surgery, St Antonius Hospital, PO Box 2500, 3430 EM Nieuwegein, the Netherlands.
Email: richte.schuurmann@gmail.com

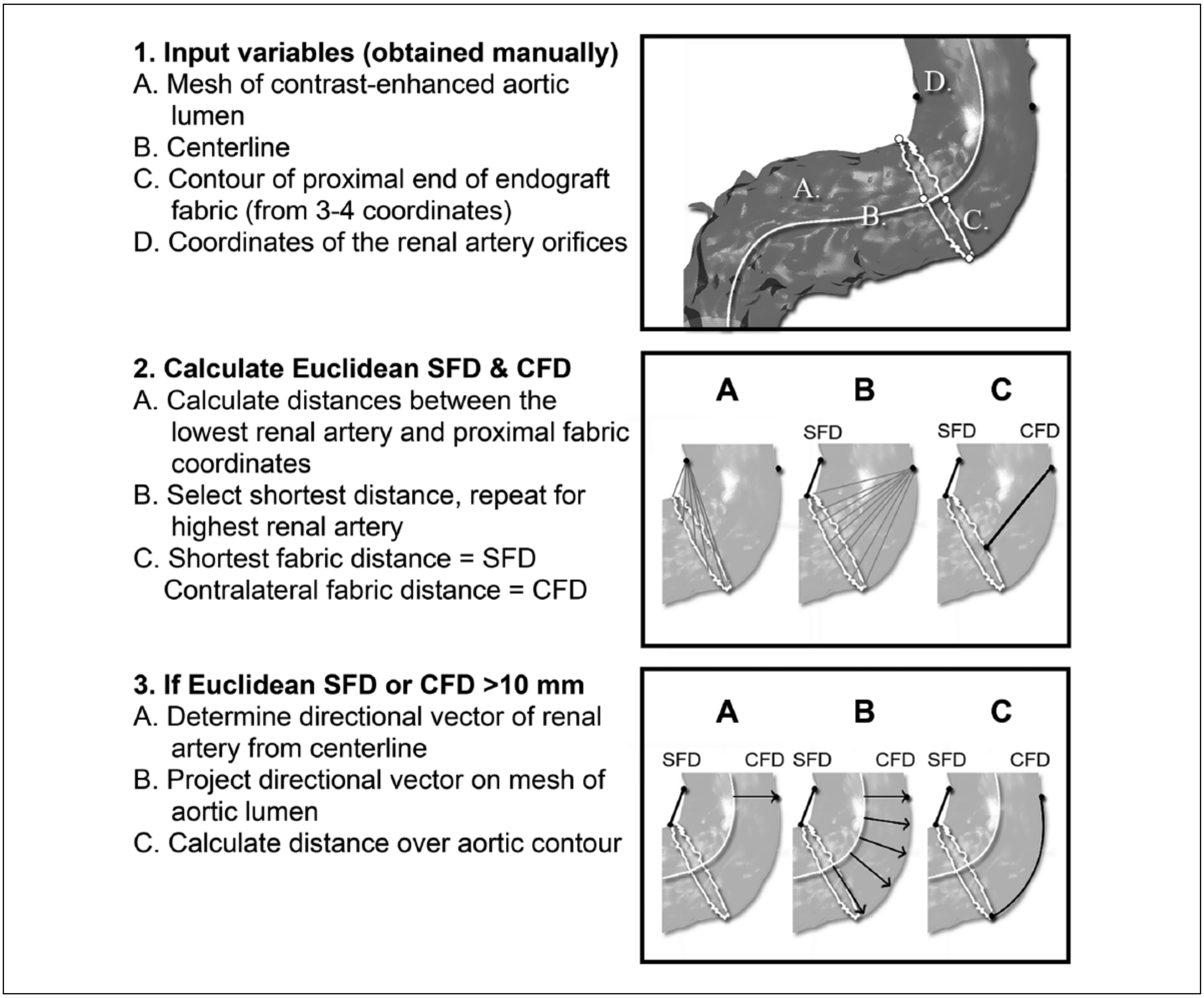

Figure 1. Step-by-step explanation of the methodology of calculating the shortest fabric distance (SFD) and contralateral fabric distance (CFD): (1) obtain the coordinates, centerline, and mesh from a vascular workstation; (2) calculate Euclidean fabric distances; and (3) if a Euclidean distance is >10 mm, the fabric distance is calculated over the curve of the aorta.

to validate a semiautomated method for determining the accuracy of endograft positioning in the aortic neck after EVAR. The methodology was used to measure the shortest 3D distances between the proximal end of the fabric and both renal arteries in a series of EVAR procedures, with the target position of the endograft fabric close to the lower renal artery. The outcome of this methodology was compared with the current gold standard, which is the manual distance along the centerline at the aortic wall, below each renal artery.

Methods

Study Design

The shortest distances between both renal arteries and the endograft fabric, further referred to as fabric distances, were automatically calculated as the minimal Euclidean distances between the distal boundaries of the orifices of the respective renal arteries and the proximal boundary circumference of the endograft fabric (Figure 1). The Euclidean distance describes the straight-line distance between 2 coordinates in a 3D space. If the Euclidean fabric distance was >10 mm, the fabric distance was calculated over the outer contours of the aortic lumen to account for curved morphology of the aortic segment. The fabric distances were calculated for both left and right renal arteries and a preserved accessory renal artery if applicable. The shortest distance between the fabric and one of the renal arteries is referred to as the shortest fabric distance (SFD) and the distance to the contralateral renal artery is referred to as the contralateral fabric distance (CFD). These distances are independent of which renal artery is defined as the lower renal artery on the

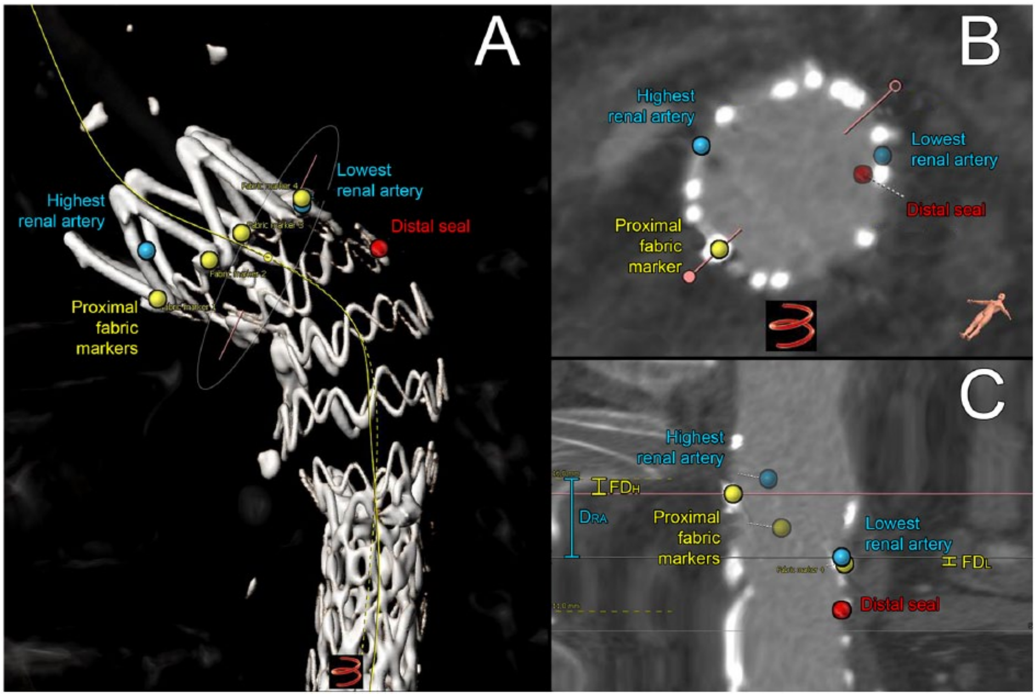

Figure 2. Postrepair computed tomography measurements on the 3mensio workstation displayed in (A) a 3-dimensional, (B) perpendicular to the centerline, and (C) stretched vessel views. Coordinates of the renal arteries, the 4 proximal fabric markers, and the distal end of the seal are displayed, as well as the centerline distances between the renal artery orifices (D_{RA}) and the fabric distances below the lower (FD_L) and higher (FD_H) renal arteries.

preoperative CT scan. The coordinates of the renal arteries and the proximal graft boundary (Figure 2) were obtained from the first postoperative 3D CT volumes on the 3mensio vascular workstation (version 8.1 research edition; Pie Medical Imaging BV, Bilthoven, the Netherlands).

Endografts involved in the study included the Endurant (Medtronic, Minneapolis, MN, USA), Zenith and Zenith Low Profile (Cook, Bloomington, IN, USA), Excluder (W. L. Gore & Associates, Flagstaff, AZ, USA), and Talent (Medtronic) endografts, which have radiopaque markers at fixed distances from the edge of the graft fabric. The exact distance between the center of these markers and the fabric edge were provided by the manufacturers (Endurant 1.3 mm, Zenith 1.3 mm, Excluder 1.5 mm, and Talent 1.3 mm). The fabric distances were calculated from the coordinates of the renal arteries and the coordinates of the proximal fabric edge, corrected for the given distances between the radiopaque markers and the actual edge of the fabric. The fabric edge of the Gore Excluder endograft with diameters <31 mm has a sinusoidal shape. For this type of endograft, the proximal graft boundary was defined by the peaks of the graft edge. Calculations were performed with proprietary custom software in Matlab 2013b (The MathWorks, Natick, MA, USA). Distances for the entire cohort are presented as the median (interquartile range, IQR).

The slope of the fabric relative to the higher renal artery was calculated as the angle of the fabric in each renal artery plane. With the lower renal artery orifice as a baseline, positive slope equals orientation of the top of the fabric toward the higher renal artery (increasing the apposition surface below the higher renal artery), while a negative slope describes an orientation away from the higher renal artery (decreasing the apposition surface). The slope was calculated as

$$\text{slope} = \tan^{-1}\left(\frac{(FD_L + D_{RA}) - FD_H}{\text{Diam}}\right) \qquad (1)$$

where FD_L = fabric distance to lower renal artery (mm), FD_H = fabric distance to higher renal artery (mm), D_{RA} = centerline distance between the higher and lower renal artery (mm), and Diam = aortic neck diameter (mm).

Automatic calculations of fabric distances over the contour of the aorta were compared with manual measurements of the fabric distances over the centerline on the stretched vessel reconstructions. For highly curved aortic segments, the distance measurements over the centerline may underestimate the distance over the outer curve. Therefore, the location of the CFD on the inner or outer curve of the aorta was reported for patients with a CFD >5 mm and average curvature over the suprarenal and/or juxtarenal aorta >10 mm^{-1}.

Study Population

A database containing 150 elective EVAR patients who served as a matched control cohort for the Aortic Securement System Global Registry (ANCHOR) was available from 3 high-volume institutions. Of these 150 patients, 145 had a preoperative and early (<60 days) postoperative CT scan. Twenty-three patients were excluded because one of these scans was a noncontrast CT scan. Another 6 were excluded because the scanned trajectory was too short or the trajectory was not sufficiently enhanced with contrast agent. Nineteen patients treated with additional materials, such as giant bare metal stents, extension cuffs, and chimneys, were excluded. Five patients were excluded because the endograft was deliberately positioned lower than directly below the level of the lower renal artery. Eleven patients were excluded because the endografts had no clear proximal boundary of the graft fabric (5 Trivascular Ovation, 2 Lombard Aorfix, 2 Endologix AFX, and 2 Endologix Powerlink). The remaining 81 patients were included in the study. Institutional review board approval was obtained, with exemption from patient consent for review of anonymized CT scans.

CT Measurement Protocol

The CT scan parameters (available for 53 patients) were tube voltage 120 kV, tube current 180 mA·s preoperative and 200 mA·s postoperative, distance between slices 0.75 mm, pitch 0.9, and collimation 128×0.63 mm preoperative and 16×0.75 mm postoperative. Iodinated contrast agent was administered intravenously in the arterial phase. The CT scan acquisition was bolus triggered when arterial Hounsfield units were >100. Median slice thickness for all included patients was 2.0 mm (IQR 1.5, 3.0) for the preoperative scan and 1.5 mm (IQR 1.5, 2.5) for the postoperative scan, which was acquired at a median 33 days (IQR 29, 42) post EVAR.

All measurements were performed by 2 experienced observers. A 3D centerline was drawn semi-automatically through the center of the aortic lumen. A mesh of the outer contours of the aortic lumen was automatically created with the mesh export tool provided by the 3mensio vascular workstation. The measurements were performed on 1-mm reconstructed slices perpendicular to the centerline. Anatomical neck characteristics were determined on the preoperative CT scan, while the endograft position was determined on the first postoperative CT scan. Aortic neck diameter was defined as the average diameter, derived from the outer wall circumference at the level of the lower renal artery. The aortic neck length was measured as the centerline distance between the distal boundary of the lower renal artery orifice and the distal end of the aortic neck (10% increase in average aortic diameter compared with the average aortic diameter at the level of the lower renal artery). The distance between the higher and lower renal arteries was measured over the centerline from the caudal levels of both renal artery orifices (Figure 2; D_{RA}).

Neck thrombus thickness was defined as the average thickness of mural thrombus over the circumference on the orthogonal slice 5 mm distal from the lower renal artery. This level includes the target zone for deployment of the endograft in most patients. Thrombus circumference was the total degree of circumference covered by >1-mm-thick thrombus. Neck calcification was calculated in a similar way as the average thickness and total circumference of >1-mm calcification on the orthogonal slice 5 mm distal from the lower renal artery.

Suprarenal and infrarenal angulations were measured as the angles between the flow direction of the suprarenal aorta to the aortic neck and the aortic neck to the aneurysm sac over the centerline based on the 2D methodology described by van Keulen and coworkers[10] and adapted for measuring along the centerline in 3D.

Aortic curvature has been described previously as a significant predictor of intraoperative and late (>1 year) type Ia endoleak.[11–13] The average curvature was calculated over 6 predefined regions: the aortic neck (between the lower renal artery and the start of the aneurysm), the aneurysm sac (between the end of the infrarenal neck and 20 mm proximal to the aortic bifurcation), and the terminal aorta (between 20 mm proximal to the aortic bifurcation and the aortic bifurcation). The aortic region surrounding the lower renal artery was further subdivided into suprarenal aortic neck (30 to 10 mm proximal to lower renal artery), juxtarenal aortic neck (10 mm proximal to and 10 mm distal from lower renal artery), and infrarenal aortic neck (10 to 30 mm distal to the lower renal artery).

Manual measurements of the fabric distances were performed by 2 experienced observers on the stretched vessel reconstructions. The centerline distances were measured from the distal boundary of the orifices of the renal arteries to the proximal boundary of the endograft fabric at the same clock positions as the renal arteries (Figure 2; FD_L, FD_H).

Statistical Analysis

Interobserver variability in measuring neck length and intra- and interobserver variability in manual measurement vs automatic calculation of the fabric distances were assessed in 24 patients with the repeatability coefficient (RC) and the intraclass correlation coefficient (ICC). The RC is defined as 1.96 times the standard deviation of the difference between 2 repeated measurements covering 95% of the expected variation.[14] The ICC was tested with a 2-way mixed model by absolute agreement. All measurements, including defining the centerline, the mesh of the aortic lumen, and measurements of the coordinates and distances,

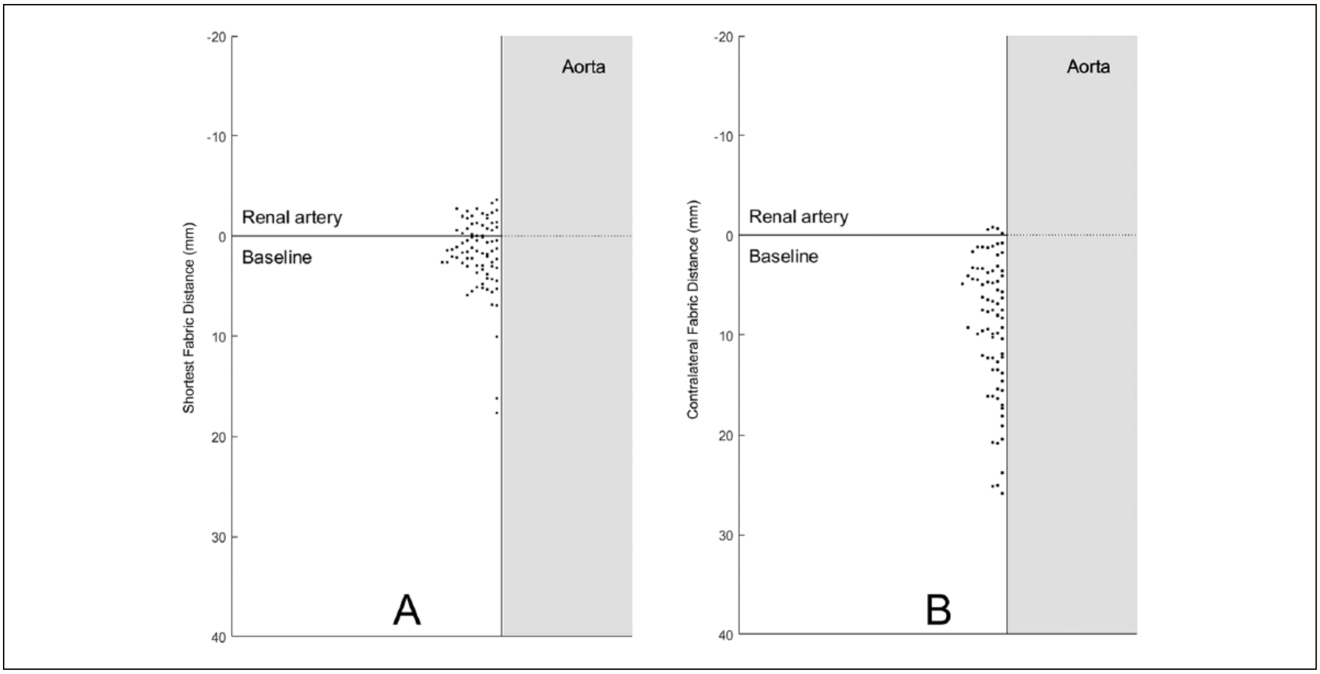

Figure 3. Distribution of (A) shortest fabric distance and (B) contralateral fabric distance on the first postoperative computed tomography scan of 81 endovascular aneurysm repair patients.

were independently performed by the 2 observers. One observer repeated the measurements with a 3-week interval.

The shortest fabric distances were subdivided into 3 categories: target position (SFD 0 to 3 mm from one of the renal arteries), high position (SFD <0 mm; partial coverage of one of the renal arteries), and low position (SFD >3 mm from the renal arteries). Differences in morphological characteristics between high and low position cohorts compared to the target position cohort were calculated with a 1-way analysis of variance. Differences in the nominal variable endograft type were calculated using cross tabulation and Pearson's chi-square test. The Shapiro-Wilk test was used to test for normality of the anatomical baseline characteristics. All measurements are described as the median and IQR (quartiles 1 and 3). The differences between the repeated measurements were normally distributed and denoted as means ± standard deviation. The threshold of statistical significance was $p<0.05$. Statistical analysis was performed with SPSS software (version 23; IBM Corporation, Armonk, NY, USA).

Results

Endograft Position

The median fabric distances calculated by the software were 1.4 mm (IQR −0.9, 3.0) for the SFD (Figure 3A) and 8.0 mm (IQR 3.9, 14.2) for the CFD (Figure 3B). The target position (SFD 0–3 mm) was reached in 36 (44%) patients, with a median SFD of 1.5 mm (IQR 0.5, 2.3) and a CFD of 8.8 (IQR 3.8, 15.6). High endograft position (partial coverage of 1 renal artery orifice) was observed in 24 (30%) patients with a median SFD of −1.9 (IQR −2.5, −1.1) and a CFD of 4.7 (IQR 1.1, 9.0). In none of these patients was the renal artery occluded by full fabric coverage. Low position was observed in 21 (26%) patients with a median SFD of 5.0 (IQR 3.7, 6.3) and a CFD of 13.5 (IQR 6.6, 18.2).

The median slope of the endograft relative to the higher renal artery (Figure 4) was 2.5° (IQR −5.5°, 13.9°). A positive slope was seen in 49 (61%) patients, indicating that the endograft was oriented toward the higher renal artery, thus increasing the apposition surface in the aortic neck.

The preoperative morphological (neck) characteristics are displayed in Table 1. A significantly higher calcification burden was observed in the cohort with high endograft position. Low position was associated with significantly higher infrarenal angulation.

Intra- and Interobserver Variability

The intra- and interobserver variability were determined for manual measurement of the fabric distances over the centerline and automatic calculation of the fabric distances over the contour of the aorta in 24 patients (Table 2). The average time for the observers to measure the characteristics and collect the coordinates for further processing was 8.0±1.5 minutes per CT angiography scan. All measurements and

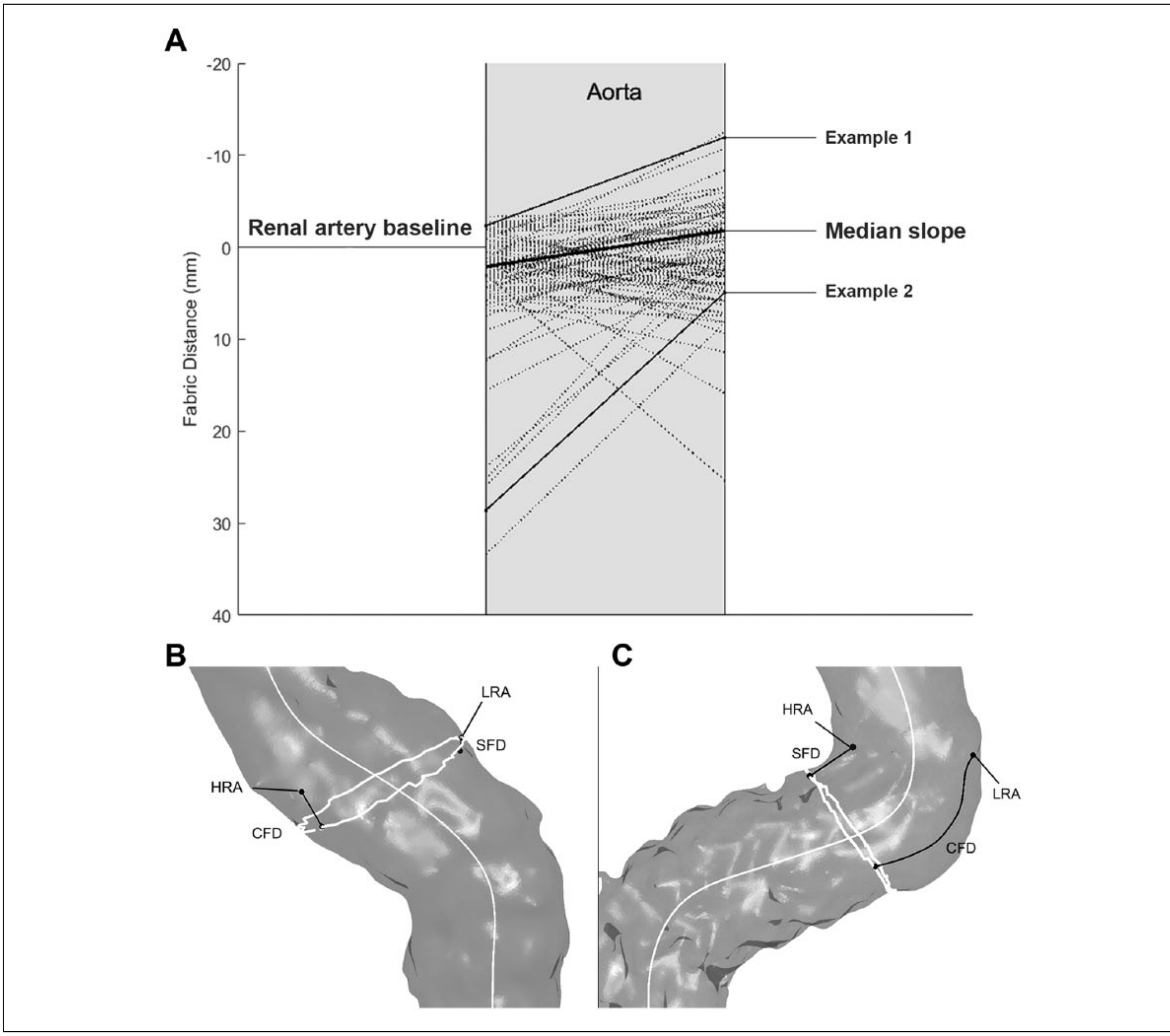

Figure 4. (A) Endograft position and orientation in the aortic neck relative to the renal artery with the shortest fabric distance in 81 endovascular aneurysm repair cases. The median slope toward the higher renal artery was 2.5° (IQR −5.5°, 13.9°). (B) Example 1: High endograft position partially overstenting the lower renal artery, with positive slope (16.6°) optimizing the apposition surface. (C) Example 2: Low endograft position with positive slope (47.9°). lower renal artery (LRA), higher renal artery (HRA), shortest fabric distance (SFD), and contralateral fabric distance (CFD) are displayed.

calculations showed excellent agreement (ICC >0.892, $p<0.001$). The mean difference between repeated manual measurements of neck length and fabric distances was 0.0 to 1.0 mm, with 95% of the variance within 4.3 and 5.2 mm. The mean difference between repeated automated calculations of the fabric distances was 0.1 to 0.8 mm with 95% of the variance within 2.6 and 3.4 mm. Manual measurements of the CFD over the centerline were ±20% lower than the automatic calculations of the CFD over the aortic contour. Twelve patients had a CFD >5 mm and suprarenal and/or juxtarenal curvature >10 mm^{-1}. Of these patients, the CFD was located in the outer curve of the aorta in 11 (92%) patients and in the inner curve in 1 (8%).

Discussion

This study introduces a new methodology to accurately determine the endograft position within the aortic neck relative to both renal arteries. Both manual measurements and automated calculations showed excellent intra- and interobserver agreement. The mean differences between repeated manual measurements, as well as automated calculations of

Table 1. Preoperative Anatomical Neck Characteristics and Postoperative Endograft Position of 3 Subgroups of Shortest Fabric Distance.[a]

	High Position (n=24)	p	Target Position (n=36)	Low Position (n=21)	p
SFD, mm	−1.9 (−2.5, −1.1)		1.5 (0.5, 2.3)	5.0 (3.7, 6.3)	
CFD, mm	4.7 (1.1, 9.0)		8.8 (3.8, 15.6)	13.5 (6.6, 18.2)	
Neck diameter, mm	23.7 (22.4, 26.3)	0.703	24.4 (20.9, 26.8)	23.1 (20.9, 24.8)	0.338
Neck length, mm	24.0 (16.0, 40.0)	0.206	20.0 (10.0, 31.8)	26.0 (15.0, 38.0)	0.833
Thrombus					
Thickness, mm	0.0 (0.0, 1.9)	0.388	0.0 (0.0, 1.5)	0.0 (0.0, 0.0)	0.569
Circumference, deg	0.0 (0.0, 104.5)	0.595	0.0 (0.0, 78.8)	0.0 (0.0, 0.0)	0.232
Calcification					
Thickness, mm	1.8 (1.1, 2.4)	0.034	1.1 (0.0, 2.0)	0.0 (0.0, 1.6)	0.075
Circumference, deg	34.5 (10.8, 61.5)	0.020	7.0 (0.0, 41.3)	0.0 (0.0, 23.2)	0.448
Suprarenal angulation	24.0 (17.2, 32.0)	0.525	22.3 (12.4, 31.1)	25.6 (10.5, 37.9)	0.390
Infrarenal angulation	53.5 (36.4, 65.0)	0.360	48.7 (35.8, 59.5)	57.1 (38.3, 90.1)	0.005
Curvature, m^{-1}					
Neck	24.9 (15.9, 33.6)	0.134	28.5 (16.1, 41.3)	21.9 (16.8, 39.6)	0.973
Suprarenal	12.7 (3.4, 16.2)	0.506	10.7 (0.6, 18.5)	12.5 (3.1, 20.5)	0.433
Juxtarenal	21.1 (15.6, 27.6)	0.976	22.1 (13.2, 31.7)	18.5 (9.6, 25.1)	0.340
Infrarenal	25.2 (15.2, 39.2)	0.533	31.0 (13.6, 37.9)	33.4 (22.6, 50.2)	0.269
Aneurysm sac	24.0 (17.8, 27.2)	0.216	23.0 (20.0, 30.6)	22.1 (18.7, 28.3)	0.272
Terminal aorta	13.5 (8.3, 22.7)	0.481	14.9 (8.5, 24.6)	14.6 (4.3, 24.0)	0.381
Maximum sac diameter, mm	55.9 (55.4, 62.7)	0.471	53.7 (47.7, 60.7)	55.3 (50.1, 68.2)	0.281
Endograft		0.437			0.871
Endurant	17		25	14	
Zenith	5		3	3	
Excluder	2		6	2	
Other[b]	0		2	2	

Abbreviations: CFD, contralateral fabric distance; SFD, shortest fabric distance.
[a]Data are presented as the median (interquartile range).
[b]Talent and Zenith Low Profile.

the fabric distances, were low and comparable with the mean difference between repeated neck length measurements presented in a large variability study by Ghatwary and coworkers.[15] The RC for the manual measurements was slightly higher compared with the findings of Ghatwary et al[15] (4.3 to 5.2 mm vs 3.1 to 4.1 mm, respectively), which may be the result of a lower number of inclusions. The variance of the automated calculations was lower than that of the manual measurements, indicating better reproducibility of the automated methodology. In most cases, the CFD was located in the outer curve of the aortic neck, which resulted in a 20% underestimation of the manual centerline measurements compared to the automatic calculations. This effect has also been described for neck length measurements by van Keulen et al.[16]

The automated methodology allows for distance calculations within 3 mm accuracy in 95% of the cases, including the orientation of the endograft (slope) relative to the higher renal artery. The SFD indicates the accuracy of the endograft placement on the first postoperative CT scan, independent of which renal artery is lower. Both SFD and CFD reflect the neck length that is not used for apposition. During follow-up, increases in both SFD and CFD indicate endograft migration.

Currently, discussions in the international EVAR community are about (short) neck length and the instructions for use, while deployment accuracy influencing effective seal in these necks is underreported in the literature. This study describes the accuracy of endograft deployment at the first follow-up CT scan, and it appears that the available neck length is not optimally utilized in a substantial proportion of the patients. In other words, treating a patient with a certain neck length does not guarantee obtaining the same length of seal postoperatively. Even for experienced endovascular teams in state-of-the-art endovascular environments, the target position within 0 to 3 mm below one of the renal artery orifices was achieved in only 44% of the cases. While assessing the effective seal length, Bastos Gonçalves and coworkers[17] looked at the deployment accuracy for the Gore Excluder and found low deployment (>5 mm centerline distance between the renal artery and the full circumference of the fabric) in 29% of the cases, which is in line

Table 2. Interobserver Variability for Preoperative Neck Length and Intra- and Interobserver Variability for Postoperative Shortest Fabric Distance and Contralateral Fabric Distance, Automatically Calculated Over the Aortic Contour by the Software and Manually Measured as the Centerline Distance.[a]

	Observer 1, Session 1	Observer 1, Session 2	p	Observer 2, Session 1	p
Neck length, mm	21.5 (10.5, 31.3)			21.5 (10.8, 27.0)	
MD, mm				0.0±2.3	
RC, mm				4.6	
ICC				0.994 (95% CI 0.986 to 0.997)	<0.001
Automatic SFD, mm	1.8 (−0.1, 3.6)	0.6 (−1.8, 3.4)		1.8 (−1.0, 4.9)	
MD, mm		−0.8±1.5		0.2±1.7	
RC, mm		2.9		3.2	
ICC		0.909 (95% CI 0.784 to 0.961)	<0.001	0.906 (95% CI 0.782 to 0.959)	<0.001
Manual SFD, mm	2.2 (−1.1, 5.4)	1.7 (−1.5, 3.7)		0.7 (−1.3, 5.5)	
MD, mm		−0.4±2.6		−0.2±2.6	
RC, mm		5.2		5.2	
ICC		0.934 (95% CI 0.848 to 0.971)	<0.001	0.892 (95% CI 0.750 to 0.953)	<0.001
Automatic CFD, mm	10.1 (3.9, 15.9)	9.9 (4.4, 16.4)		10.3 (4.3, 15.6)	
MD, mm		0.1±1.3		−0.3±1.7	
RC, mm		2.6		3.4	
ICC		0.990 (95% CI 0.978 to 0.996)	<0.001	0.984 (95% CI 0.962 to 0.993)	<0.001
Manual CFD, mm	8.2 (4.7, 12.5)	8.2 (5.0, 11.7)		8.1 (3.7, 10.9)	
MD, mm		0.5±2.2		−1.0±2.0	
RC, mm		4.3		3.9	
ICC		0.973 (95% CI 0.938 to 0.988)	<0.001	0.957 (95% CI 0.885 to 0.982)	<0.001

Abbreviations: CFD, contralateral fabric distance; CI, confidence interval; ICC, intraclass correlation coefficient; MD, mean difference; RC, repeatability coefficient; SFD, shortest fabric distance.
[a]Data are given as the median (interquartile range) or mean ± standard deviation unless otherwise noted.

with our findings. Benharash and coworkers[18] measured the centerline distance between the superior mesenteric artery and the proximal end of the stent and showed that increased distance was associated with a higher risk of migration after 1 year. Since accuracy of endograft deployment may be associated with failure of seal and fixation, this information should be used during procedure planning and should be considered in studies that describe anatomical predictors of sealing failure. The current study cohort is underpowered to analyze the association between suboptimal deployment and post-EVAR complications and seal failure.

Low deployment was associated with increased infrarenal angulation, suggesting that accurate deployment is more challenging in severely angulated necks. Previous findings by our group showed that aortic curvature is a better predictor than angulation for acute and late failure of proximal seal, but it seems that deployment accuracy is associated with the total angle, rather than with the intensity of the curve.

High endograft position, which was seen in 30% of the cases, might be associated with renal malperfusion, since the renal artery is partially overstented by the endograft. In this study, no renal arteries were fully occluded by overstenting. New onset permanent dialysis after EVAR was observed in one of the high position patients, with partial obstruction of the renal artery orifice. This patient had a history of type II diabetes and decreased renal function prior to the EVAR procedure.

The median distance between the lower and higher renal artery was 5.0 mm, and a positive slope of the fabric of the endograft toward the higher renal artery (observed in 61% of the cases) would be beneficial to optimize apposition. Repositionable devices or delivery systems with a deflectable tip may be of help to better align the main body with the centerline of the aortic neck and to minimize the tilt of the endograft relative to the aortic neck.

Limitations

The small sample size of the position subgroups prohibited analysis of renal function, device-specific position, and complication rates. While the slope of the endograft in the renal artery plane indicates the orientation of the top of the fabric toward or away from the higher renal artery, the slope does not necessarily designate endograft alignment with the aortic neck but rather the benefit or loss of apposition on the aortic neck. Tilted alignment of the endograft toward the axis of the aortic neck may result in the salami slice effect, causing unintended undersizing of the endograft. This effect may occur not only in the renal artery plane but also in the anterior-posterior direction. Therefore, appreciation of the tilt requires complex 3D analysis, which is beyond the scope of this article.

Successful automated wall detection requires sufficient contrast agent in the lumen of the aortic neck. Application of the software is therefore limited by inadequate or noncontrast CT scans. For the latter, manual measurement of the fabric distances is required.

Conclusion

The novel methodology enables precise evaluation of endograft deployment within the proximal aortic neck on post-EVAR CT scans, facilitating accurate assessment of endograft position relative to the renal arteries. Variability of automated calculation of the fabric distances was lower than that of manual measurements, and the automatic calculations accounted for curved aortic neck morphology. In this series only 44% of endografts were placed within 3 mm of the lowermost renal artery orifice during EVAR. Hence, treating a patient with a certain calculated pre-EVAR neck length does not guarantee achieving the same length of seal post-EVAR.

Declaration of Conflicting Interests

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